A Newly Discovered "Highly Accessible" NEO

The Minor Planet Center reported discovery of near-Earth object (NEO) 2012 UV_{136} on 24 October 2012. Orbit data inferred from initial 2012 UV_{136} observations are available from the Jet Propulsion Laboratory's *Horizons* ephemeris service at http://ssd.jpl.nasa.gov/?horizons and are used throughout this report. *Horizons* data indicate closest approach to Earth will occur 10.3 November 2012 UT at a distance of 2.2 million km. At that time, 2012 UV_{136} is crossing Earth's orbit inbound toward perihelion at 87% Earth's distance from the Sun on 26 January 2013.

In lieu of any planetary radar observations for 2012 UV_{136}, its effective spherical diameter d must be estimated based on *Horizons* absolute magnitude $H = 25.57$. These estimates produce d = 13 m to 59 m, assuming a plausible albedo ranging from 60% to 3%, respectively. While 2012 UV_{136} has unremarkable dimensions, its orbit is arguably the third most accessible among known NEOs. An authoritative, if subjective, accessibility metric is provided by the NEO Human Space Flight Accessible Targets Study (NHATS, pronounced "gnats") website at http://neo.jpl.nasa.gov/nhats/. Using default accessibility criteria, NHATS tallies the number of compliant round-trip trajectories to 2012 UV_{136} with launch dates from 2015 through 2040, arriving at the sum n = 2,105,050 using data available on 1 November 2012. This value is exceeded only by NEOs 2000 SG_{344}, (n = 3,302,718; d = 19 m to 85 m) and 1991 VG (n = 2,737,560; d = 4 m to 16 m) under the same default NHATS criteria.

Both 2000 SG_{344} and 1991 VG have an orbit condition code $OCC = 2$, meaning their respective orbit solutions are stable, even over decades of position prediction into the past or future. Consequently, we could hope to reliably plan human or robotic missions to these highly accessible NEOs when opportunities arise. With only 49 observations extending over a 9-day interval, 2012 UV_{136} has $OCC = 5$ as of 1 November 2012. Although a minimal number of observations with poor quality can drive OCC values as high as 9, a few nominal-quality observations will typically achieve $OCC = 6$. Additional observations over a more extended period will be necessary before 2012 UV_{136} OCC can be reduced to 3 or less. At $OCC > 3$, this NEO's recovery after passing into Earth's daytime sky during mid-November 2012 may be problematic.

There is real hope for further 2012 UV_{136} OCC reduction because its orbit period is currently less than 2% longer than Earth's. In October 2013, this NEO should therefore be just about as observable as at its discovery. These two observing windows, with 2012 UV_{136} crossing Earth's orbit inbound towards perihelion, are illustrated in Figure 1. Dotted projection lines onto Earth's orbit plane (the ecliptic) in Figure 1 indicate 2012 UV_{136} is slightly below/south of the ecliptic when Earth's orbit is crossed inbound before perihelion and slightly above/north of the ecliptic when Earth's orbit is crossed outbound after perihelion. Small position deviations from the ecliptic by 2012 UV_{136} are due to its 2.3° orbit inclination with respect to that plane.

Inbound Earth orbit crossings are at an ecliptic longitude corresponding to November in Earth's orbit, and Earth happens to be very nearly in-phase with 2012 UV_{136} at these crossings in 2012 and 2013. Outbound crossings of Earth's orbit occur at ecliptic longitudes corresponding to April/May, and reasonably in-phase approaches with Earth will not occur there until 2019. Assuming 2012 UV_{136} OCC is low enough for reliable planning, any of these in-phase Earth orbit crossings offers a human mission opportunity with relatively short duration and low propulsion requirements.

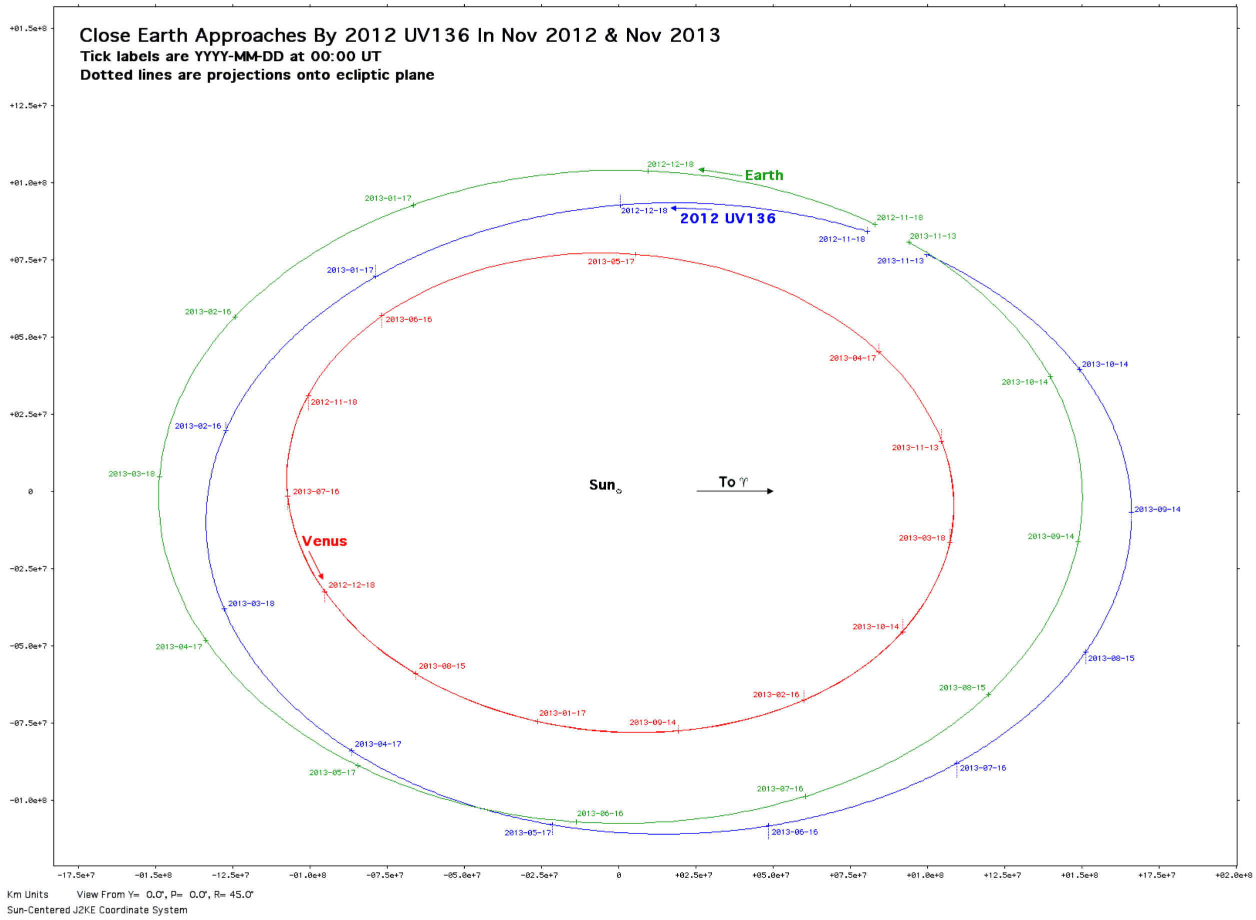

Figure 1. This heliocentric inertial plot shows the motion of Venus (red), Earth (green), and 2012 UV$_{136}$ (blue) during the year following this NEO's discovery. Perspective is from 45° above/north of the ecliptic.

Phasing trends for 2012 UV$_{136}$ with respect to Earth over multiple heliocentric revolutions are best inferred using a relative motion coordinate system rotating with the Earth/Sun line. Figure 2 utilizes such a system, called Local Vertical Curvilinear (LVC), to illustrate 2012 UV$_{136}$ geocentric relative motion over the 3-year interval centered near its discovery date. Locations to the right of Earth in Figure 2 are ahead of Earth in its heliocentric orbit, and locations to the left are behind. Direction towards the Sun is downward throughout Figure 2 because the horizontal LVC axis running through Earth (called the Vbar) maps a heliocentric circular arc. Consequently, 2012 UV$_{136}$ tends to move rightward when located below the Vbar in Figure 2 and move leftward when located above the Vbar. Perihelion for 2012 UV$_{136}$ occurs near the bottom of each Figure 2 LVC loop, and aphelion occurs near the top of each loop.

The gross phasing trend over one or more LVC loops in Figure 2 is leftward, indicating 2012 UV$_{136}$ spends more time outside Earth's orbit than inside it. An Earth orbit crossing by 2012 UV$_{136}$ in Figure 2 corresponds to a Vbar crossing. Because 2012 UV$_{136}$ tends to phase behind Earth and also crosses its orbit, it is a member of the Apollo class of NEOs.

Phasing trend variations are most easily perceived among the 4 Vbar crossings with 2012 UV_{136} inbound toward the Sun at the left of Figure 2. Note particularly the spacing of these November crossings along the Vbar in years 2011 through 2014. The greatest phase rate occurs between the 2011 and 2012 inbound Vbar crossings. Because the close Earth approach in November 2012 occurs with 2012 UV_{136} *leading* Earth in its heliocentric orbit, gravity perturbations from Earth lower both aphelion and perihelion. As a result, phase rate from November 2012 until the next Earth close approach in November 2013 is reduced with respect to the preceding year. The more distant Earth approach in November 2013 occurs with 2012 UV_{136} *trailing* Earth in its heliocentric orbit, partially neutralizing Earth perturbations accumulated in 2012. An intermediate phase rate is therefore apparent in Figure 2 from November 2013 until November 2014.

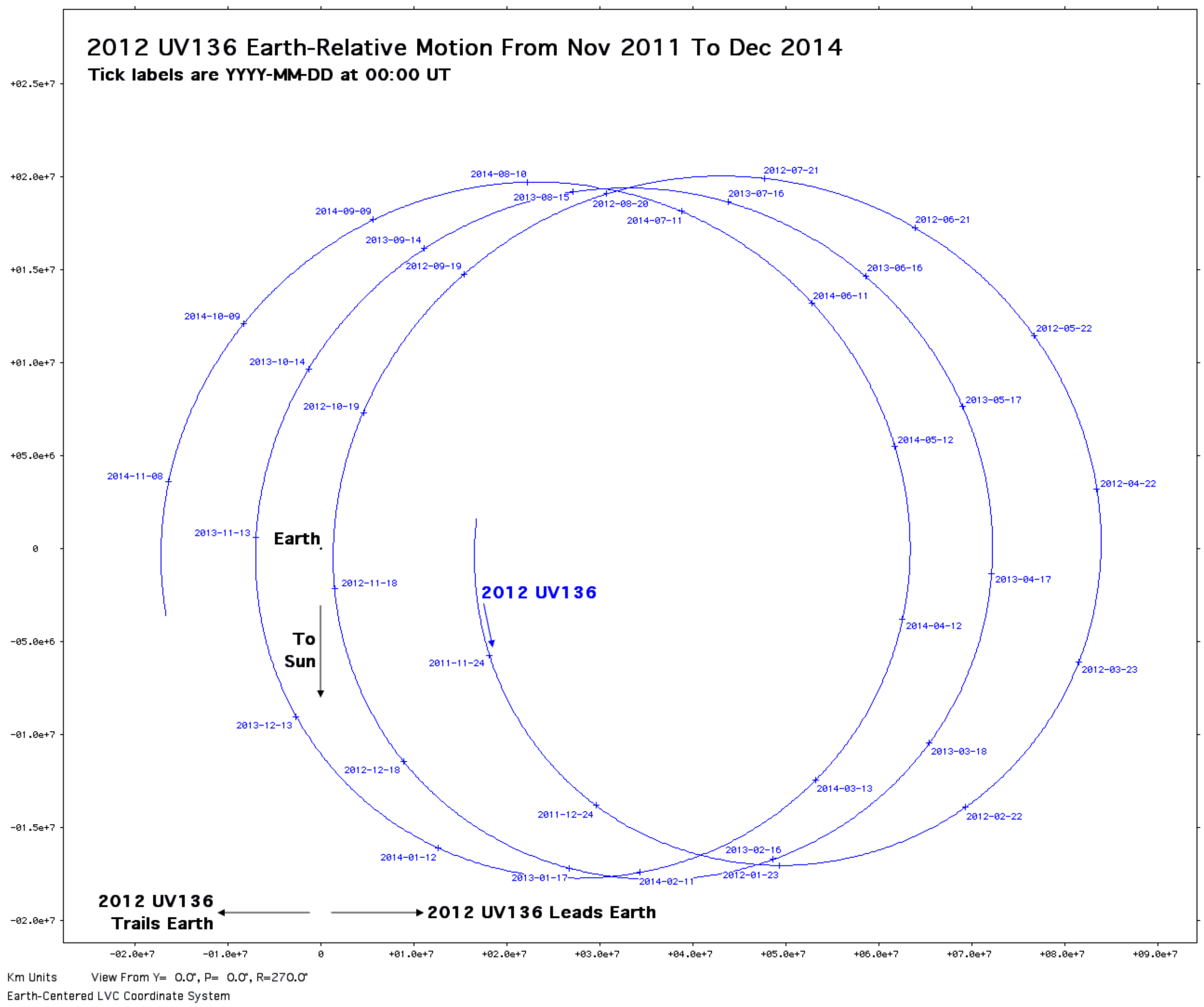

Figure 2. This geocentric plot of 2012 UV_{136} motion projected onto the ecliptic plane is in a coordinate system rotating with the Earth/Sun line. It permits detailed study of Earth perturbations accumulated by this NEO over multiple orbits.

After the November 2013 Earth approach, 2012 UV_{136} phase rate remains reasonably constant until additional outbound Vbar crossings in April/May approach Earth closely beginning in

2019. Additional Earth perturbations will be accumulated by 2012 UV_{136} over the ensuing several years. *Horizons* predictions into the mid-2020s indicate 2012 UV_{136} will have an orbit period of 370 days after Earth perturbations from outbound Vbar crossings have run their course. Approximate heliocentric angular rates for Earth and 2012 UV_{136} can be computed as the quotients $\omega_1 = 360/365 = 0.9863°$/day and $\omega_2 = 360/370 = 0.9730°$/day, respectively. The difference $\omega_1 - \omega_2 = 0.0133°$/day approximates 2012 UV_{136} heliocentric phase rate with respect to Earth. Ignoring further perturbations, this phase rate permits Earth to catch up with 2012 UV_{136} and begin additional close approaches (along with human mission opportunities) after one synodic period $T_S = 360/0.0133 = 27{,}068$ days = 74 years.

Despite having an Earthlike orbit, 2012 UV_{136} could also have abysmally low NHATS accessibility as measured by *n* if missions are constrained to launch at times other than the default interval from 2015 through 2040. Launch date constraints are but one of many subjective aspects relating to NEO accessibility for human space flight. An orbit period similar to Earth's may facilitate a NEO's observation from Earth over an extended time interval, but this condition may also place an otherwise accessible NEO on the other side of the solar system from Earth during a programmatically convenient launch season.